Issues and Opportunities

Introduced Species: Introduced species have had a significant impact throughout the Bay-Delta ecosystem, and they can pose a significant impediment to achieving restoration objectives. In order to minimize the risk of potentially massive ecological and biological disruptions associated with non-native species-disruptions that could threaten to negate the benefits of restoration efforts-it is important to initiate an early program that:

- prevents or significantly reduces additional introductions of non-native species,
- develops a better understanding of how non-native species affect ecological processes and biological interactions,
- develops effective control and eradication programs, and
- establishes habitat conditions that favor native over non-native species.

Decline in Productivity: Productivity at the base of the foodweb has declined throughout the Delta and northern San Francisco Bay. Although some of this decline can be attributed to the introduced clam Potamocorbula amurensis, or Asia clam, not all of the decline is explained. The decline at the base of the foodweb has been accompanied by declines in several (but not all) species and trophic groups, including mysids and longfin smelt. The long-term implications of this seem to be a reduction in the capacity of the system to support higher trophic levels. This implies a limit on the extent to which Bay-Delta fish populations can be restored unless creative solutions can be found to increase foodweb productivity (Strategic Plan 2000).

Opportunities in the Delta: Reduce the introduction of ballast-water organisms from ships to 5% of 1998 levels. The shipping industry can be required to greatly reduce and eventually eliminate the introduction of organisms through ballast water using existing technology. Significant progress could also be made in reducing the introduction of non-native species from other sources as well (goal 5, objectives 2-7). This is a preventative rather than a restorative activity. Given the impacts that introduced invasive species have already had on the ecology of the Bay-Delta ecosystem, however, the eventual elimination of all additional species introductions is crucial to the ultimate success of the ERP (Strategic Plan 2000).

Research: Initiate targeted research on major restoration issues, such as: (1) how to control problem invasive species such as the Asia clam (Potamocorbula amurensis), which has a negative effect on foodweb dynamics in the estuary; (2) factors limiting the abundance of high-priority endangered species; and (3) design of habitats for shallow-water tidal marsh and bypasses. Ultimately, the limited funds available for restoration will be much more effectively spent if there is a clear understanding of the relative seriousness of the diverse problems facing the estuarine and riverine ecosystems and of the ability to solve those problems. Where the research can be linked to pilot or large-scale restoration projects, the benefits will be multiplied (Strategic Plan 2000).

Vision

The vision for invasive aquatic organisms is to reduce their adverse effects on the foodweb and on native species resulting from competition for food and habitat and direct predation.

This vision can be accomplished through enforcement of State laws regulating ballast water dumping and other measures designed to reduce the number of new, potentially harmful species introduced accidentally into the Bay-Delta estuary. Habitat changes or direct control measures may reduce their effects in specific cases.

The introduction of non-native species to the Bay-Delta has been a mixed blessing. Most have successfully integrated into the Bay-Delta aquatic community. Others, however, have hastened the extinction or greatly reduced the abundance of native species or have become an economic nuisance. Once established, non-native species cannot be effectively removed by harvesting or poisoning, except perhaps in small localized areas.

The only practical way to minimize the spread of non-native species and promote the growth of native species is to restore the habitats to more natural conditions. Restoring more natural, native aquatic communities should promote greater ecosystem stability by reducing the likelihood of catastrophic reductions in abundance of native organisms resulting from changes in environmental conditions.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore the natural environmental conditions, trophic status and native invertebrate community of the Bay-Delta will involve the cooperation and support of established programs underway to restore habitat and fish populations in the basin.

- Restoration of the plankton food supply of native fishes is a primary focus of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (U.S. Fish and Wildlife Service 1995).
- The Central Valley Project Improvement Act (CVPIA) calls for the doubling of the anadromous fish populations (including striped bass, salmon, steelhead, sturgeon, and American shad) by 2002, through changes in flows and project facilities and operations. This program involves actions that may directly or indirectly benefit native invertebrates of the Bay-Delta foodweb.
- The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988) to restore numbers of anadromous fish in the Central Valley. Actions include restoring the food supply of anadromous fish.
- Efforts will be coordinated by the State Water Resources Control Board and Regional Water Quality Control Boards to reduce the amount of toxic substances released into Central Valley waterways, which should help reduce stresses on the native and non-native invertebrate species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Invasive aquatic organisms adversely influence other ecosystem elements including ecological processes, habitats, and species. For example, introduced species have out competed and displaced many native species. The proliferation of these exotic organisms has altered the Bay-Delta foodweb.

OBJECTIVES, TARGETS, ACTIONS, AND MEASURES

There are many Strategic Objectives related to invasive aquatic organisms.

> The first Strategic Objective is to eliminate further introductions of new species from the ballast water of ships into the Bay-Delta estuary.

LONG-TERM OBJECTIVE: Eliminate the dumping of all organism-contaminated ballast water and ballast sediment into the estuary.

SHORT-TERM OBJECTIVE: Eliminate the dumping of all ballast sediment into the estuary. Reduce the amount of ship ballast water contaminated with estuarine organisms from other ports that is dumped into the estuary to 5% of 1998 levels by the year 2005, and to 1% of 1998 levels by 2008.

RATIONALE: The introduction of non-native species in the ballast water of ships has made the estuary the most invaded estuary in the world; a new species is being added about every 14 weeks. The new species greatly increase the expense and difficulty of restoring the estuary. A new invader can effectively destroy the value of a restoration project. Aquatic invasions also have harmed public health, decimated fisheries, and impeded or blocked water deliveries. Substantial reductions in the number of organisms released via ballast water are readily achievable. Around the world, restrictions and regulations governing management of ballast water and other ballast materials are being promulgated to reduce the introduction of non-native species by this means. Strict controls on ballast water exchange should be enacted and enforced on shipping into San Francisco Bay at the earliest possible time. If prevention cannot work, the shipping industry must be made responsible for the damage caused by ballast water organisms because such introductions must be regarded as deliberate and unauthorized, rather than "accidental."

STAGE 1 EXPECTATIONS: Same as short-term objectives. In addition, better mechanisms to treat ballast water to eliminate unwanted organisms will have been developed. Baseline monitoring of the organisms released in ballast water should be immediately initiated so we can assess progress and monitor compliance. Studies should be completed to investigate the ecological and economic impacts of introductions into the Bay-Delta system to demonstrate that strong action is warranted.

> The second Strategic Objective is to eliminate further introductions of new species from imported marine and freshwater baits into the Bay-Delta estuary and its watershed.

LONG-TERM OBJECTIVE: Eliminate the use of imported live non-native freshwater and marine species for bait in San Francisco Bay and elsewhere in California.

SHORT-TERM OBJECTIVE: Develop and institute strategies, working with the bait industry, the fishing community, and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of organisms used as bait in fresh and brackish water.

RATIONALE: At the present time, polychaete worms are shipped live from New England and southeast Asia to the San Francisco Bay Area for use as bait in marine sport fisheries. The New England worms are packed in seaweed which contains many non-native organisms, some of which have been established in San Francisco Bay as a result. This is thus an example of small activity that has the potential for large-scale economic damage (see ballast water rationale). It should be banned by the Fish and Game Commission and the baits replaced by local organisms or by artificial bait.

Many kinds of aquatic organisms are used for bait. Bait fishes like the red shiner have been spreading rapidly and now dominate many streams, with unknown impacts on native fishes and on fisheries. They continue to be spread by anglers releasing unused bait. Other new organisms may be brought in as "hitch-hikers" in shipments of bait fishes. There is also a need to better educate the fishing public on the adverse impacts of invasive species.

STAGE 1 EXPECTATIONS: The importation of live marine baits and their associated shipping materials will have been banned, unless the industry can demonstrate that all the organisms imported cannot become established in California.

Working with the bait industry and other interested parties, a plan will have been developed and instituted to greatly reduce, and eventually eliminate, the introduction of unwanted bait organisms into natural waters.

> The third Strategic Objective is to halt the unauthorized introduction and spread of potentially harmful non-native introduced species of fish and other aquatic organisms in the Bay-Delta and Central Valley.

LONG-TERM OBJECTIVE: Prevent the establishment through deliberate introductions of any additional fish species from outside the state or from other watersheds within the state, into Central California.

SHORT-TERM OBJECTIVE: Develop a program to educate the public (especially anglers) about the dangers of moving fish and other organisms around.

RATIONALE: The California Department of Fish and Game has long had a policy of not bringing new aquatic species into California to improve fishing. However, illegal introductions continue, such as that of northern pike into Davis Reservoir. If the highly predatory pike had become established in Sacramento River and Delta, it is quite likely it would have had devastating impact on salmon and native fish populations. There is a need to develop stronger prevention strategies for illegal introductions. The conflict that developed around the necessary elimination of pike from Davis Reservoir demonstrates the need for the development of better public understanding of the need to halt invasions. Education is also needed to make the point that any movement of fish and aquatic organisms by humans to new habitats is potentially harmful, even if the species is already established nearby. Brook trout introduced into a fishless mountain lake, for example, can eliminate the population of mountain yellow-legged frog that lives there, pushing the species further towards endangered species listing.

STAGE 1 EXPECTATIONS: An aggressive public information program should be developed in regard to species introductions.

> The fourth Strategic Objective is to halt the release of non-native introduced fish and other aquatic organisms from private aquaculture operations and the aquarium and pet trades into the Bay-Delta estuary, its watershed, and other central California waters.

LONG-TERM OBJECTIVE: Halt the non-deliberate introduction into natural waters of aquatic organisms from aquaculture facilities that is often a by-product of aquaculture operations. Prevent the importation from other regions of organisms from other regions into aquaculture facilities in the Bay-Delta system unless major quarantine regulations or facilities are in place.

SHORT-TERM OBJECTIVE: Institute an independent, scientific assessment of the pathways and risks of the introduction into the environment of organisms imported from other regions by aquaculture and of any changes needed in California's current management of the industry to prevent such introductions. Develop and institute strategies, working with the aquaculture industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of invasive or harmful non-native species via aquaculture.

Develop and institute strategies, working with the aquarium industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of non-native species from the aquarium and pet trades.

RATIONALE: Stocks of fishes and invertebrates are imported from other regions for rearing in aquaculture facilities in the Bay-Delta system, and permits are occasionally approved to bring in new species for aquaculture. Numerous examples exist of organisms escaping from aquaculture facilities and becoming established outside of their range. These include, or potentially could include, fish, crayfish and other shellfish that could compete with or prey on native California fish and aquatic organisms, and on sport and commercial fish in central California waters. Of greater concern is the potential for the introduction of parasites and diseases of commercial, recreational, and native fish and shellfish. There are also many examples of such diseases introduced by aquaculture into various parts of the world, sometimes with devastating impact on commercially important species.

Many kinds of aquatic organisms are sold in aquarium and pet stores. It is likely that some species of nuisance aquatic plants (e.g., Hydrilla) became established through aquarists dumping them in local waterways. Non-native turtles originating in pet stores are frequently present in ponds and have the potential to displace and spread diseases to native pond turtles. Although many organisms sold in aquarium stores are tropical and unlikely to survive in Central California (with some surprising exceptions), the industry is constantly searching for and bringing in new species from a variety of habitats. As indicated in the ballast water rationale, new species can have unexpected and sometimes large-scale negative impacts on aquatic ecosystems and can make restoration much more expensive and difficult. There clearly is a need to make sure that potentially harmful organisms are not available to aquarists and that new organisms are not brought in as "hitch-hikers" in shipments of aquarium fishes. There is also a need to better educate the public on the adverse impacts of invasive species and the need to not release aquatic pets into natural environments. A good model for this could be the program now in place in Hawaii, which (among other things) has a big public education component and requires all aquarium stores to have a special tank into which people can release unwanted aquatic organisms.

STAGE 1 EXPECTATIONS: An independent assessment of the pathways, risks and needed management of aquaculture introductions will have been completed; management measures to eliminate by-product introductions will have been adopted and implemented.

Species in the aquarium and pet trades will have been identified and evaluated for their ability to establish populations in the Bay-Delta system. With the cooperation of the aquarium/pet industry and affected interests, a plan will have been developed and instituted to greatly reduce, and eventually eliminate, the introduction of unwanted aquatic organisms from these sources into natural waters.

The fifth Strategic Objective is to limit the spread or, when possible and appropriate, eradicate population of non-native invasive species through focused management efforts.

LONG-TERM OBJECTIVE: Eliminate, or control to a level of little significance, all undesirable non-native species, where feasible.

SHORT-TERM OBJECTIVE: Eradicate or contain those species for which this can readily be done, gaining thereby the largest benefit for the least economic and environmental cost; and to monitor for the arrival of new invasive species and, where feasible, respond quickly to eradicate them.

RATIONALE: Non-native species are now part of most aquatic, riparian, and terrestrial ecosystems in California. In most instances, control is either not possible or not desirable. However, in some instances, control of invasive species is needed to protect the remaining native elements or to support human uses. Four factors should be considered in focusing control efforts. First, an introduced species is often not recognized as a problem by society until it has become widespread and abundant. At that point, control efforts are likely to be difficult, expensive, and relatively ineffective, while producing substantial environmental side effects or risks, including public health risks. Second, some organisms, by nature or circumstance, are more susceptible to control than others. Rooted plants are in general more controllable than mobile animals, and organisms restricted to smaller, isolated water bodies are in general more controllable than organisms free to roam throughout large, hydrologically connected systems. Third, although biological control is conceptually very appealing, it is rarely successful and always carries some risk of unexpected side effects, such as an introduced control agent "controlling" desirable native species. And fourth, physical or chemical control methods used in maintenance control rather than eradication require an indefinite commitment to ongoing environmental disturbance, expense, and possibly public health risks. Overall, the most efficient, cost-effective, and environmentally beneficial control programs may be those that target the most susceptible species, and species that are not yet widespread and abundant. This suggests a need to (1) assess the array of introduced species and focus on those that are most amenable to containment and eradication, rather than focusing just on those that are currently making headlines, and (2) responding rapidly to eradicate new introductions rather than waiting until they spread and become difficult or impossible to eradicate.

An example of a "rare" introduced species needing eradication that is not being dealt with is English cordgrass in the Bay. It has been described by some scientists as the most aggressive and invasive salt marsh plant in the world. It has been in the Bay, its only known California location, for 20 years without spreading, so it has not generated concern. However, in other parts of the world it has also sometimes sat around for a few decades without doing much of anything, then suddenly taken off and taken over entire estuaries in a few years. In San Francisco Bay, it is known from one site only, where it was planted, and where it exists in a single patch. It could readily be eradicated.

An example of an abundant species needing immediate attention is the water weed Egeria densa. This plant has been spreading rapidly through the Delta, where it clogs sloughs and channels with its dense growth, creating problems for navigation. From a biological perspective, it is undesirable because E. densa beds appear to exclude native fishes and favor introduced species.

STAGE 1 EXPECTATIONS: An assessment will be completed of existing introductions to identify those with the greatest potential for containment or eradication, and consider this in prioritizing control efforts. A program will have been implemented to monitor for, and respond quickly to contain and eradicate new invasions, where this is possible. A mechanism whereby new invasions can be dealt with quickly and effectively will have been developed an implemented.

RESTORATION ACTIONS

The general target for invasive aquatic organisms is control and reduce the incidence of introductions and to implement control programs or eradicate exotic species where possible.

Actions that would help achieve this vision include more stringent enforcement of current policies regarding the introduction of non-native species. These policies seek to prevent the introduction of known noxious species and minimize the introduction of all other species. In addition to prohibiting intentional introductions, enforcing existing laws such as International Maritime Organization's Guidelines will reduce the number of accidental introductions from ship ballast water.

MSCS Conservation Measures

The following conservation measures were included in the Multi-Species Conservation Strategy (2000) to provide additional detail to ERP actions that would help achieve species habitat or population targets.

- Implement applicable management measures identified in the restoration plan for the Anadromous Fish Restoration Program and the recovery plan for the native fishes of the Sacramento/San Joaquin Delta.
- Implement management measures identified in the proposed recovery plan for the Sacramento River winter-run chinook salmon.

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◆ INVASIVE RIPARIAN AND MARSH PLANTS

INTRODUCTION

Invasive riparian and marsh plants have become sufficiently established in some locations to threaten the health of the Bay-Delta ecosystem. The riparian and salt marsh plants that pose the greatest threats to aquatic ecosystems are those that directly or indirectly affect rare native species, decrease foodweb productivity, and reduce populations of desired fish and wildlife species.

Factors that relate to the degree of influence invasive riparian and salt marsh plants have on the Bay-Delta include additional introductions from gardens and other sources, and ground disturbances and hydrologic regimes that create favorable conditions for their establishment.

STRESSOR DESCRIPTION

Weeds, or invasive plant species, are organisms capable of invading relatively undisturbed habitats and exploiting opportunities provided by natural or human-related disturbances in the landscape. Although not all weeds are non-native, most have been introduced from other parts of the world. In the absence of the natural biological controls found in their native habitats, such as herbivory by specific insects, weeds can flourish with fewer constraints in a new landscape, quickly gaining a competitive advantage over the native species. Many weeds have also evolved characteristics that make them extraordinarily competitive in both native and non-native environments. These specialized traits may include high seed production, both sexual and asexual reproduction, several methods of dispersal, a fast growth rate, and tolerance of a wide range of environmental conditions such as extremes in temperature, nutrients, and water availability.

A plant species becomes a weed problem when it adversely affects natural communities or land uses. Whether non-native or native, plant species are considered harmful when they reduce the biological diversity of existing natural communities by displacing native species or altering ecosystem processes such as nutrient cycling, hydrologic conditions, or the frequency of fires. They are problems to human society when they impair agricultural productivity, present fire hazards, constrict waterways, diminish recreation and aesthetic value, or destroy structures.

Since the first non-native settlers, weeds have been introduced to California and many have become established. There were at least 16 non-native plant species established by 1869, 292 by 1925, 797 by 1968, and 1,023 by 1993 (Barbour et al. 1993). Undoubtedly, non-native species introductions will continue, and correspondingly, add pressure on the native plant communities and the wildlife that depend on them.

More than 90% of the State's historic riparian habitat has been lost, primarily as a consequence of land being converted for agricultural uses (Barbour et al. 1993). What remains continues to be threatened, not only by further habitat conversions, but also by weeds. It is particularly important for the many endangered and threatened species that weeds are controlled, particularly for birds and fish that depend on native riparian plant communities.

Many riparian infestations are from species, such as Pampas grass, that spread from gardens. Others were planted intentionally along engineered or altered waterways for erosion control or in the belief that native vegetation would be too vigorous and would clog waterways (Dawson 1984). Weed infestations in riparian and salt marsh systems are magnified by both alterations to the landscape and current land use patterns. Clearing land allows weeds that thrive in disturbed areas, such as ailanthus, to invade bare areas and move into established forests. Overgrazing in riparian areas can diminish recruitment of new native trees and shrubs directly and indirectly by contributing to the establishment of a dense understory of non-native vegetation that hinders native seedling establishment. Some orchards may be a source of riparian weed infestations, as may have happened with the establishment of California black walnut, used as rootstock in English walnut orchards.

Urban development adjacent to riparian areas can lead to infestations by ornamental garden plants such as German ivy, arundo or giant reed, elm, black locust, and edible fig. Increases in summer ground and surface water from irrigation can harm some riparian vegetation, altering the species composition. It can create conditions leading to a higher rate of invasion by urban area weeds such as Bermuda grass that can compete with native seedlings, thus affecting forest regeneration. Left alone, many weeds can take over part or all of the established riparian or salt marsh communities, displacing the native vegetation and becoming the new climax successional species. Examples include arundo and tamarisk. Both were intentionally introduced and now are widespread weeds that have displaced extensive areas of native riparian vegetation throughout the western United States.

Most Central Valley and Delta riparian communities are confined to lower floodplain and river channel areas, compared to a much wider distribution over vast floodplains 150 years ago. With the conversion of riparian communities to other land uses, broad outer bands of riparian vegetation were lost or their extent greatly diminished, like those dominated by sycamores.

Today, most watercourses are confined to narrower channels with little room for changing patterns of braiding and migration. Inundation and sedimentation rates are altered from historical times in river channels and are substantially reduced in floodplain areas. In the Delta, sedimentation is also altered with the erosion of islands.

Habitat losses or alterations have resulted in a pattern of habitat fragmentation. Riparian communities are often disconnected patches along river channels, and salt marshes are either newly developed from sediment deposition or smaller patches of formerly great expanses. The alteration of ecosystem processes like sedimentation, nutrient flow, fire, and hydrologic conditions, along with reduction in cover and native plant community diversity, has resulted in degraded riparian or salt marsh habitat conditions. The riparian or salt marsh community is then vulnerable to invasions by non-native species that are better adapted to the altered conditions than the native vegetation.

Species such as arundo and tamarisk are able to quickly exploit disturbed riparian sites. They, in turn, alter the ecosystem processes further, changing the frequency of fires, increasing shade and sediment capture, armoring the streambed and banks, altering soil salinity (tamarisk), and modifying the hydrologic patterns. The native species are not adapted to the new ecosystem processes, and the introduced weeds dominate the successional community.

Weeds that pose the greatest threats to riparian and salt marsh areas are those that out compete and exclude native vegetation and diminish habitat value to wildlife and reduce biodiversity of native species. All weeds listed in the following section have this potential.

Numerous weeds threaten the establishment and succession of native riparian and salt marsh vegetation in the Delta and along the Sacramento and San Joaquin Rivers and their tributaries. Some of the most invasive, listed below, include weeds that are widespread, often extensive, and extremely dangerous because of their ability to dominate riparian or salt marsh communities and affect ecosystem processes (arundo and tamarisk). Other invaders are trees or shrubs that now dominate portions of riparian forests and can invade larger areas if not controlled (ailanthus, edible fig, northern California black walnut, eucalyptus, black locust, and Russian olive). Additional examples include some weeds that are primarily a problem in a more restricted range or ecological zone type (perennial pepperweed, German ivy, cordgrass, and purple loosestrife).

Both arundo and tamarisk are widespread weeds capable of causing enormous damage to California riparian communities. They reduce biological diversity, habitat value for wildlife, and ecosystem processes such as flooding patterns and fire frequency.

ARUNDO (*Arundo donax*), also known as giant reed or false bamboo: Native to the Mediterranean area, arundo was introduced to California in the late 1800s and used for erosion control along drainage canals. It continues to be sold and planted as an ornamental. Arundo is a highly invasive bamboo-like perennial grass that can form large, fast-growing, monospecific stands that out compete and displace native riparian vegetation while restricting water flow, increasing sedimentation, and forming large debris piles in streams and rivers. It is not considered to be of value to native wildlife. Arundo spreads by growing rhizomes (lateral roots) and disperses to new sites when stems and rhizomes break off in floodwater and take root in moist streambed soils. Grading and other construction activities can and have greatly increased areas occupied by arundo. For example, Camp Pendleton's past program for clearing native vegetation to conserve water resulted in distributing arundo throughout the cleared area. When the program was halted, the arundo population continued to expand (Reiger 1988).

The effects of arundo's ability to alter ecosystem processes may be profound. It is far more susceptible to fire than native riparian species. However, although it recovers from fires, most native vegetation does not, leading to increased postfire dominance by arundo. By increasing sedimentation after establishing in stream channels, arundo stabilizes islands, hinders braiding and shifting patterns in stream channel movement, and prevents native stream channel vegetation from establishing (Peterson pers. comm.). An example of this can be seen at Stony Creek in northern California. Because arundo has a vertical structure, it does not overhang water like native riparian vegetation. The result is less shade over water, providing less cover, increased water temperatures, and altered water chemistry, all conditions that can harm fish and other existing aquatic organisms and ultimately change the aquatic species composition

By 1993, arundo accounted for as much as 50-60% of a 1,116-acre riparian community in the Riverside west quadrangle covering a portion of the Santa Ana River in southern California (Douthit 1993). Because of this, it has been implicated in the reduction of rare native stream fish populations in the Santa Ana River (Bell 1993). Some arundo populations have been mapped in southern California (Douthit 1993), and a population has been mapped along Stony Creek in northern California; however, no comprehensive statewide mapping of arundo has been conducted. Therefore, an accurate assessment of the extent and rate of spread of the weed is unknown. It is widespread throughout the Sacramento and San Joaquin River channels and their tributaries, as well as throughout the Delta. More survey mapping is needed to determine the extent of arundo, the levels of threat posed by the weed throughout the ERPP study area, how and when best to safely control it, and a prioritized strategy for removing it.

TAMARISK (*Tamarix chinensis, T. ramossisima, T. pentandra*), also known as salt cedar: This woody shrub from Eurasia was introduced in the early 1800s as an ornamental. It has since spread or been introduced into nearly every drainage system in the southwestern United States. It occupies 1.5 million acres nationwide and 16,000 acres in California. It can alter ecosystem processes such as the frequency of fires and hydrologic conditions of streams and groundwater. Tamarisk plants evapotranspire larger quantities of groundwater than do native plants, leading to reduced groundwater supplies. It traps more sediment than native vegetation, leading to a reshaping of stream bottoms and altered flooding pattern. It adds increased fuel loads to the riparian community, which can result in more fires. Tamarisk tolerates fires; native riparian species generally do not. The result of these ecosystem process changes is the eventual exclusion or reduction in cover by native plant species and altered stream shapes and flooding patterns. Studies have shown that bird usage is lower when tamarisk, rather than native tree species, dominates the riparian zone (Meents et al. 1984, Anderson and Ohmart 1984).

Tamarisk is widespread in California rivers; however, an accurate assessment of the extent and rate of spread of the weed is unknown. Like arundo, more survey mapping is needed to determine the extent of tamarisk, the levels of threat posed by the weed, the best time to safely control it, and a prioritized strategy for removing it.

Ailanthus, edible fig, northern California black walnut, eucalyptus, and black locust are examples of invasive trees or shrubs that have achieved local dominance in riparian forests in the ERPP study area. All have the potential for population expansions.

AILANTHUS (*Ailanthus altissima*), also known as tree-of-heaven: Ailanthus was first introduced into the eastern United States in the late 1700s. By the mid-1800s, it was commonly sold by nurseries as a street and shade tree. It was introduced into California in the 1850s. Its horticultural popularity declined by the mid-1900s, and it became naturalized in mostly ruderal areas, but is often present in riparian habitats as well, especially those in agricultural or urban settings (Hunter 1995). Although it may not be as aggressive an invader as other riparian weeds, it has achieved local dominance in some sites, either displacing or preventing native riparian species from establishing. In agricultural settings, ailanthus roots can disrupt the integrity of levees and irrigation canal banks.

EDIBLE FIG (*Ficus carica*): Fig is a cultivated tree native to the Mediterranean area. Its seeds are dispersed by birds and other wildlife and by floodwaters. Present in many streams and rivers throughout California, it tends to form a shady canopy that can hinder seedling establishment by native species. It also spreads vegetatively through stump sprouting and where bent branches take root, thus forming thickets that exclude native species. An example of the fig's impacts may be seen at both the Dye Creek and Cosumnes River Preserves in northern California, where active management programs are in place to eradicate the trees.

NORTHERN CALIFORNIA BLACK WALNUT (*Juglans californica var. hindsii*): Historically, the native northern California black walnut was present only along the Sacramento River between Freeport and Rio Vista (Fuller 1978). However, Skinner and Pavlik (1994) say it historically grew in Contra Costa, Napa, Sacramento, Solano, and Yolo Counties. It is a special-status species in its native range; however, it (or a hybrid of it and the English walnut, *Juglans regia*) is now common in many Central Valley, Delta, and Bay Area riparian forests. The walnut's widespread distribution may be explained by its historical use as rootstock in English walnut orchards and possibly by active spread by Native Americans. Along the mainstem of the Sacramento River, there are dense areas of northern California black walnut saplings established under the canopy of mature valley oaks and cottonwoods. Without active management, these trees could eventually displace valley oaks and cottonwoods in many areas.

EUCALYPTUS (*Eucalyptus* spp.): Eucalyptus trees are native to Australia. They have been used commercially as fuel wood and planted horticulturally in urban settings. They are fast-growing and quickly form canopies that restrict available light from slower-growing native species. They also compete for water and form a large leaf litter layer that alters the soil chemistry and tends not to break down rapidly. The oil in the trees makes them particularly hazardous to fires, as was demonstrated in the Oakland hills and southern California fires in the summer of 1996. However, unlike native riparian plants, eucalyptus resprouts after fires. This combination of characteristics leads to dominance and expansion of the trees in riparian systems. Because the leaves are not broken down, the leaf litter can cause increased sedimentation in streams, adversely affecting invertebrate and fish populations. Eucalyptus trees growing in stream channels at maturity create flood risks because their shallow roots and large stature render them vulnerable to blow down and toppling during storm events, potentially causing debris dams during high flows. Volunteer eucalyptus stands in the channel may be found in many riparian locations, such as along Putah Creek in Yolo County.

BLACK LOCUST (*Robinia pseudoacacia*): Black locust is native to the eastern United States and is planted horticulturally in California. Once established, it spreads through seed and rhizomes to form locally dominant patches that can exclude native vegetation. Like eucalyptus, black locust resprouts after fires. Examples of its dominance may be found in sites along the Delta and lower American River and at the Cosumnes River Preserve.

Russian olive, perennial pepperweed, German ivy, cordgrass, and purple loosestrife are weeds that pose problems in a more restricted range or ecological zone type compared to the other listed weeds.